Cryogenic Selective Surfaces—How Cold Can We Go?

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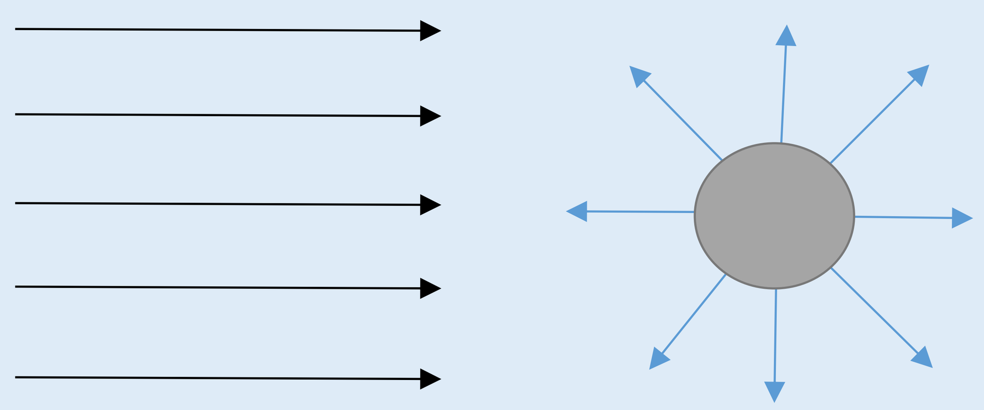
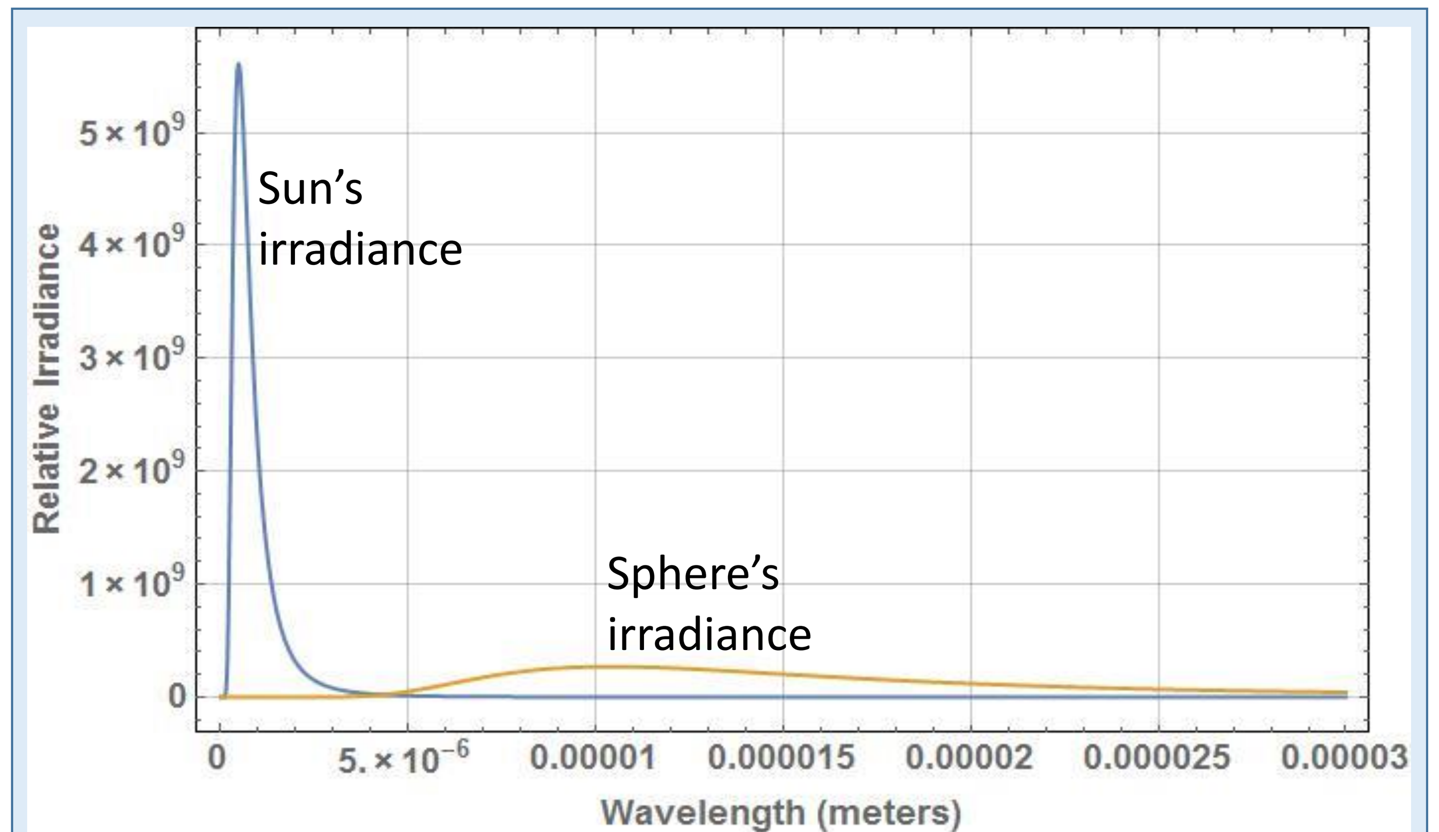


The sphere radiates thermal energy.

Radiation from the sun hits the sphere.

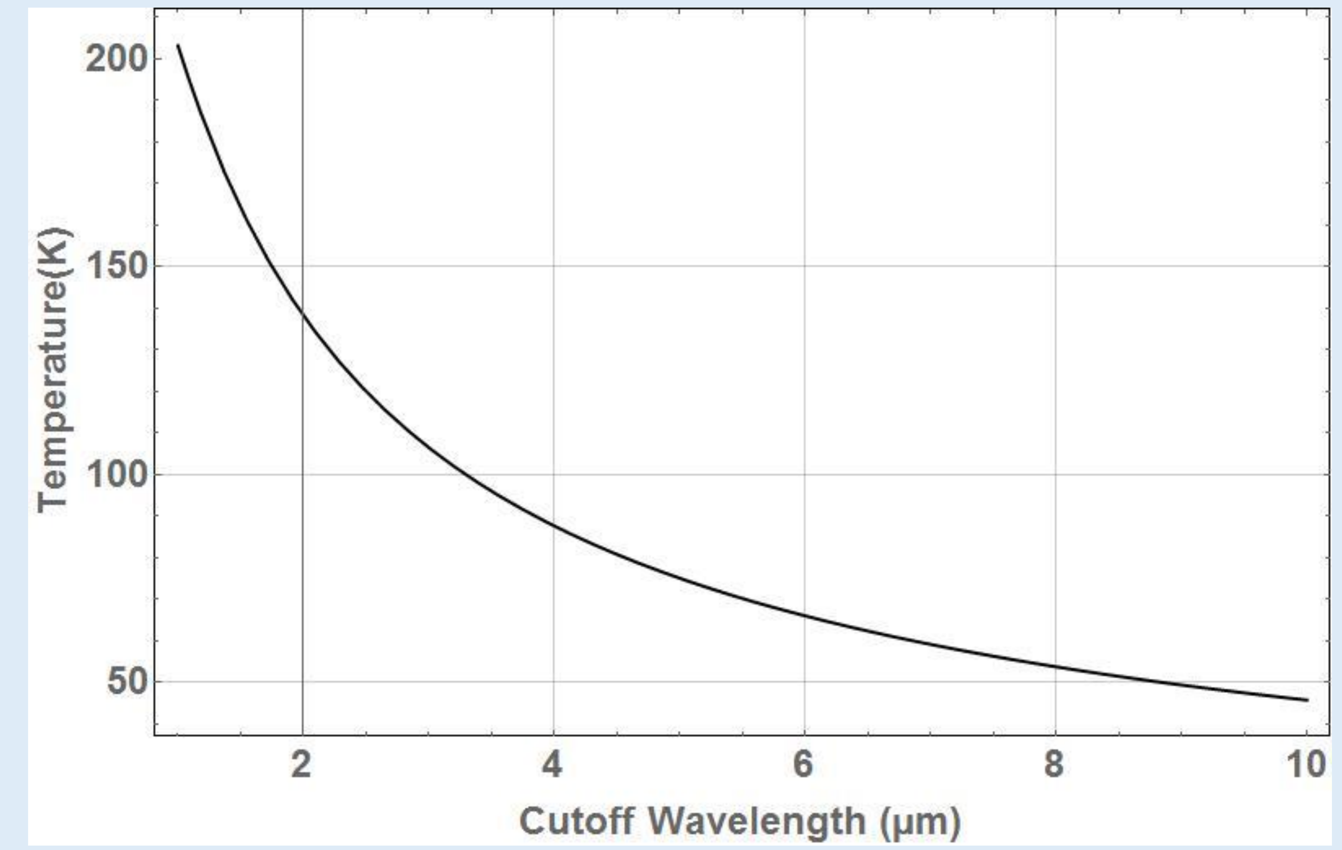
A solid sphere of aluminum sitting in deep space at 1 A.U. from the sun.

Assuming constant emissivity the sphere will reach an equilibrium temperature of about 280 K (about 42 degrees F). The Earth on average is warmer than this due to greenhouse effects.



The area under the curves is equal (energy in equals energy out), but the sun's irradiance is at a much shorter wavelength than the irradiance produced by the sphere.

We can design surfaces that reflect one and absorb the other—**Selective Surfaces**.



Coating with:

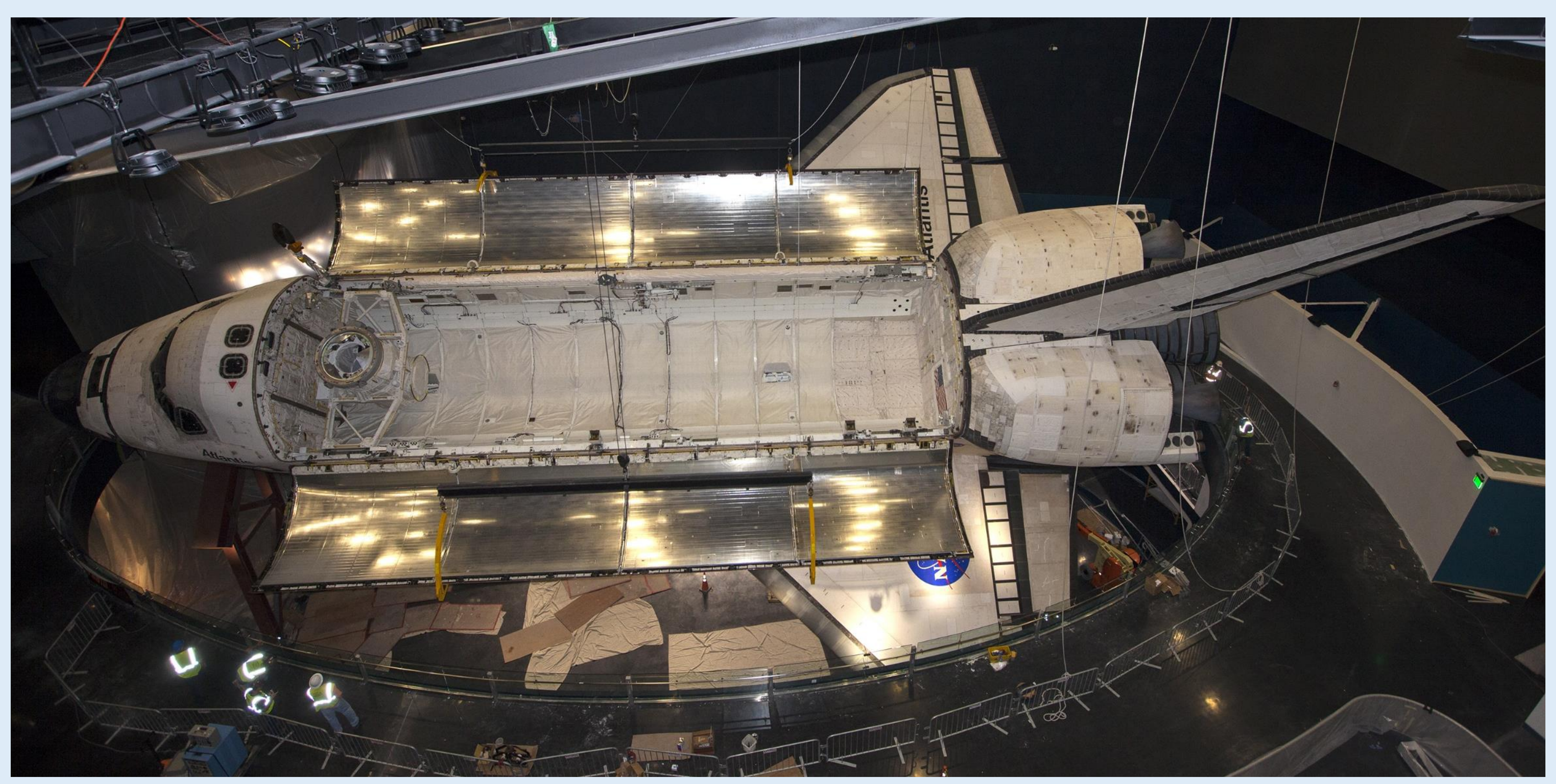
An ideal plastic might allow us to reach 150 K.

A sapphire type material might reach 75 K

And a MgFl type material might reach 50 K.

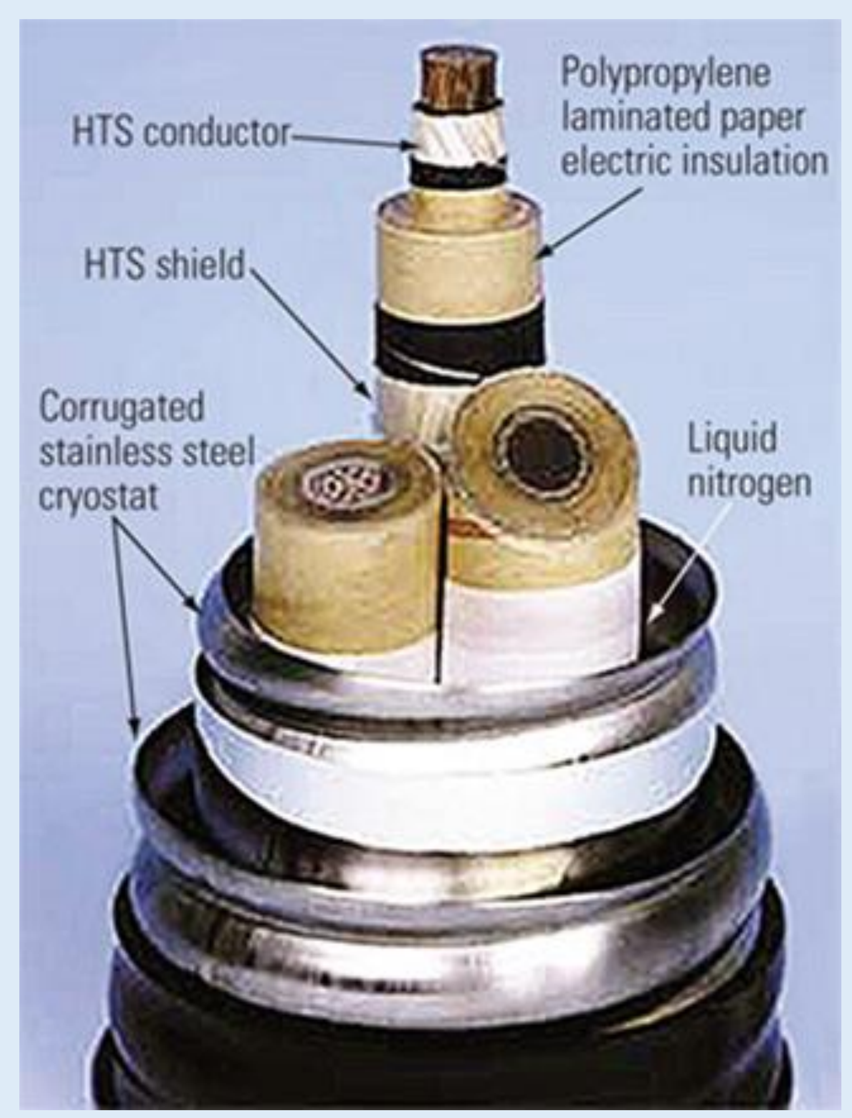
If we polish the sphere so it reflects all radiation perfectly and coat it with a material that perfectly transmits below the cutoff wavelength and perfectly absorb above it, then this plot shows the thermal equilibrium temperature of the coated sphere.

Selective Surfaces are already used in space, but not to reach cold temperatures and not in unprotected areas.



The Payload Bay doors of the Space Shuttle Orbiter were coated with a selective surface (aka thermal control coating) to allow heat rejection even in the presence of the sun.

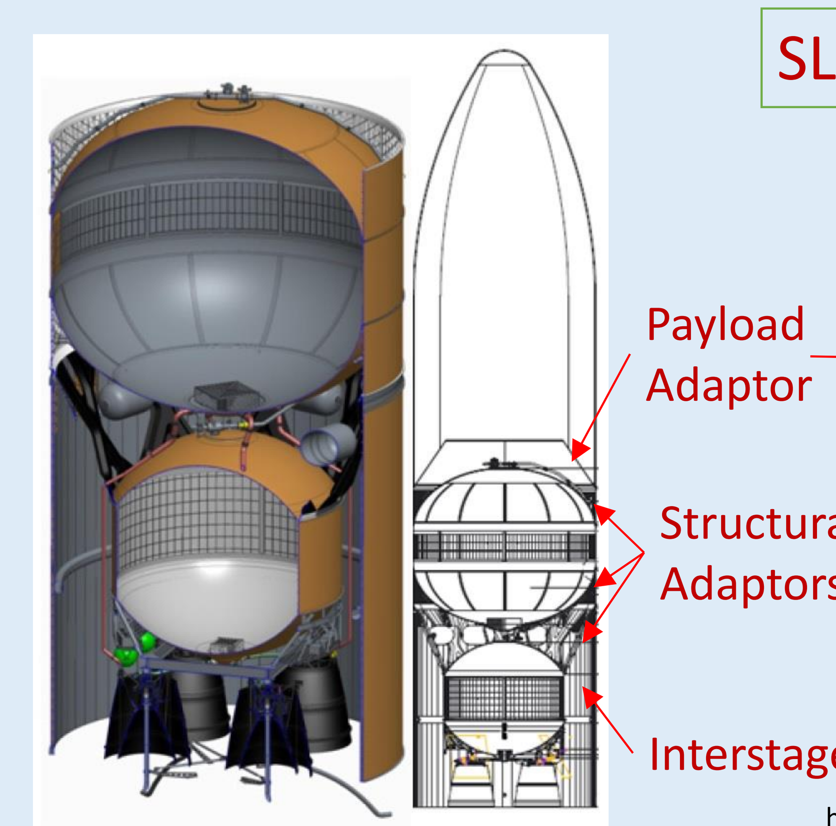
Can we go superconducting without LN2?



Hibbard (1961) showed we could reach 40 K with ideal materials. But with real world materials it isn't clear. We need to model or test cubes made of, for example, silver coated with sapphire.

Can we maintain LOX on a trip to Mars?

SLS Upper Stages



http://seradata.com/SSI/wp-content/uploads/2014/10/EUS.jpg

http://www.nasaspaceflight.com/wp-content/uploads/2012/03/Z315.jpg

The largest source of heat to LOX and LH2 tanks in orbit is conduction from warm attached structures (e.g. the stage adaptors and interstages). If a selective surface can be put onto these external surfaces, lowering their temperature, then the propellant boil-off can be substantially decreased (credit to Wesley Johnson at GRC). We will examine this in addition to coating the tank itself.

We need to model real world selective surfaces in the presence of the sun and warm structures to find their equilibrium temperatures. We need to find materials that can be installed onto the surface of a space item and that will retain its optical properties in space over long time periods.